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(54) Super-abrasive machining tool and method of use

(57) A super-abrasive machining apparatus utilizes both a means (12) for grinding a workpiece (18) and a means (14) for revolving the workpiece (18) in order to efficiently and cost effectively remove material from a workpiece (18) comprising superalloy materials or even ceramic material. The means (12) for grinding revolves at a much greater velocity than the revolving workpiece (18) to facilitate the removal of material from the workpiece (18). The workpiece (18) may be ground to remove material in order to reduce its diameter or size, to machine features into its surface and/or to impart non-continuous features into its surface.

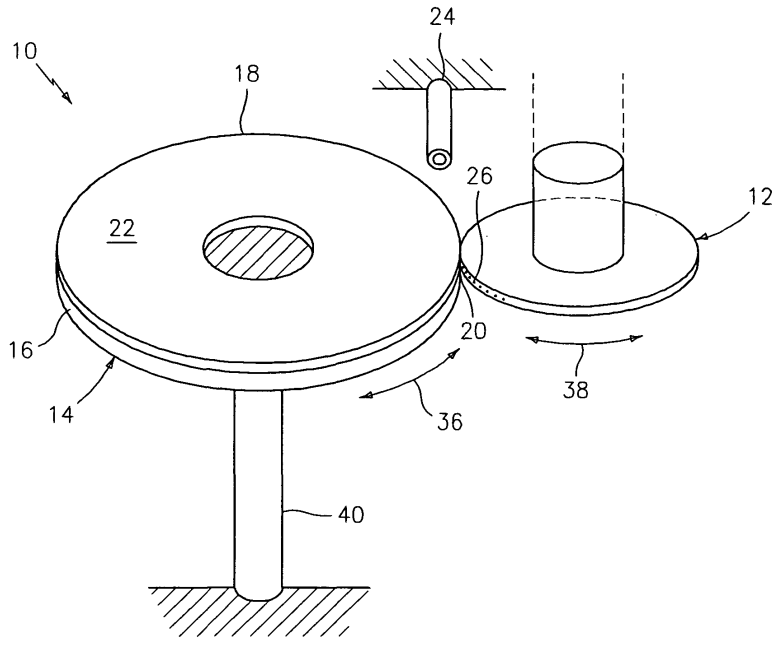

FIG. 1

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Description

FIELD OF USE

[0001] The present invention relates to a super-abrasive machining tool and its methods of use.

BACKGROUND OF THE INVENTION

[0002] A very common method of removing large volumes of material with either simple or complex shapes at the radius is turning. The material removal rate for materials such as aluminum and steel has been successfully cut for many years with conventional turning. Turning processes generally employs a lathe or a similar revolving mount to hold and revolve a workpiece while a stationary tool is applied to the surface of the revolving workpiece to remove material. This process works well with cylindrical shaped parts that are smooth at the outer radius and are not interrupted by geometric features at the outer surface of the part. This method is effective for many materials with varying hardnesses including superalloys, nickel alloys, titanium and ceramics. With these harder materials, however, tool wear and the material removal rates are limited based on the hardness of the material. The turning processes can wear tools relatively quickly, that is within minutes, when machining high hardness materials such as nickel and titanium superalloys. As a result, the turning process becomes very costly and inefficient due to the set up time consumed when replacing tools.

[0003] Consequently, there is a need for a process to machine superalloy materials in a more cost effective, efficient manner.

SUMMARY OF THE INVENTION

[0004] In one embodiment, a super-abrasive machining tool mounted in a machining center comprises a computer operated multi-axis grinding apparatus, the tool comprises means for grinding a workpiece comprising an exterior surface including a super abrasive material coating, wherein the means for grinding revolves at a first velocity in a first direction; means for cooling the means for grinding; and means for revolving a workpiece comprising a mount, wherein the means for revolving revolves in a second direction at a second velocity less than the first velocity.

[0005] In another embodiment, A method for super-abrasively grinding a workpiece comprises disposing a workpiece in a super-abrasive machining tool, wherein the super-abrasive grinding machining tool comprises means for grinding and means for cooling the workpiece; rotating the workpiece in a first direction and at a first velocity; rotating the means for grinding in a second direction and at a second velocity greater than the first velocity; grinding the workpiece using the means for grinding; and cooling the workpiece being ground.

[0006] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 is a representation of a super-abrasive machining tool and workpiece in accordance with the present invention;

FIG. 2 is a representation of another embodiment of a super-abrasive machining tool and workpiece in accordance with the present invention; and

FIG. 3 is a representation of yet another embodiment of a super-abrasive machining tool and workpiece in accordance with the present invention.

[0008] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0009] The present invention relates to a super-abrasive machining tool and methods of its use. The super-abrasive machining tool utilizes both a means for grinding a workpiece and a means for revolving the workpiece in order to efficiently and cost effectively remove material from a workpiece comprising superalloy materials or even ceramic material. Generally, the workpiece is mounted in the tool and revolves, for example, in a clockwise direction, while the means for grinding revolves in the same or opposite direction and makes contact with the revolving workpiece. The means for

grinding revolves at a much greater speed than the revolving workpiece which facilitates the removal of material from the workpiece. The workpiece may be ground to remove material in order to reduce its diameter or size, to machine features into its surface and/or to impart non-continuous features into its surface. Although the workpiece comprises a substantially circular shape, for example, circular, oval, oblong, and the like, the workpiece may comprise other geometric and non-geometric shapes having smooth exterior surfaces or one or more non-continuous or continuous features on the surface of the workpiece.

[0010] Referring generally now to FIGS. 1-3, a super-abrasive machining tool in part is shown. The super-abrasive machining tool may be mounted in a machining center comprising any suitable computer operated multi-axis grinding or milling machine known in the art. The super-abrasive machining tool may be moved by the pre-programmed, computer operated machine center to provide the desired shape of the workpiece and/or the desired features on the surface of the workpiece.

[0011] Referring specifically now to FIG. 1, a super-abrasive machining tool 10 may be mounted in a machining center comprising a base and at least two members for supporting a means for grinding 12 and a means for revolving 14. Means for revolving 14 may include an axis 40 and a mount 16 upon which a workpiece 18 is preferably disposed. Means for revolving 14 may revolve in a clockwise or counter-clockwise direction 36. Means for grinding 12 may also revolve in clockwise or counter-clockwise direction 38, and may revolve in the same direction or in the opposite direction as direction 36 of means for revolving 14. During operation means for grinding 12 makes contact with a point 20 on the workpiece surface 22. A means for cooling 24 may also be disposed proximate to means for grinding 12 and workpiece 18. Means for cooling 24 may dispense a cooling fluid including but not limited to water, oil, and the like, prior to and during the application of the means for grinding 12.

[0012] Means for grinding 12 may comprise any grinding tool comprising an exterior surface having a super-abrasive coating, that is, a grit material 26 applied to a majority of its surface area, preferably about 70 to 75% of its surface area. Preferably, grit material 26 is formed from a super-abrasive material selected from the group consisting of plated cubic boron nitride, vitrified cubic boron nitride, diamond, synthetic diamond, combinations comprising the foregoing super-abrasive materials, and the like. The super-abrasive material 26 that coats the means for grinding may have a grit size in the range of 40/45 to 325/400 depending on the depth of the cut and the hard surface finish. Grit material 26 may be applied to the surface area using any suitable technique known in the art including but not limited to electroplating, vitrified process, combinations comprising the foregoing methods and the like.

[0013] Generally, means for grinding 12 may comprise any grinding tool comprising an exterior surface having a super-abrasive coating. Preferably, means for grinding 12 comprises a grinding wheel, a quill or a small wheel as known to one skilled in the art, and the like as represented in FIGS. 1 and 2. Means for grinding 12 may grind workpiece 18 at a point of contact 20 of workpiece 18 such as along its circumference in order to remove material and reduce the diameter, and ultimately the size, of workpiece 18 as represented in FIG 1. In the alternative, means for grinding 12 may also be oriented such that its longitudinal axis 30 is at an angle α with respect to the surface of the workpiece 18 in order to impart a feature as represented in FIG. 2. For example, longitudinal axis 30 of means for grinding 12 may be aligned at an angle with respect to the axis 32 of workpiece 18 such that the point of contact 20 may be along the exterior surface, rather than circumferential surface, of workpiece 18. In the alternative, means for grinding may comprise a grinding tool having one or more non-continuous features on its exterior surface. For purposes of illustration, means for grinding 12 may be a wheel having a super-abrasive coating disposed upon a contoured exterior surface 42 as shown in FIG. 3. Such contoured exterior surface 42 having grit material 26 may be utilized to produce interrupted non-continuous features 44 in workpiece 46, remove material from existing non-continuous features of workpiece 46, impart non-continuous features or other features to the surface of workpiece 46, combinations of such applications, and the like. Such non-continuous features 44 may comprise any features such as grooves, channels, and the like, and/or shapes such as squares, rectangles, u-shapes, and the like, to form, for example, teeth as illustrated in FIG. 3. In such embodiments, the workpiece may be kept stationary during grinding (i.e. its velocity is zero).

[0014] In operation, a method for super-abrasively machining a workpiece broadly comprises the steps of providing the super-abrasive machining tool and orienting the tool relative to a surface of a workpiece so that there is at least one point of contact between the workpiece surface and the super-abrasive coating or grinding surface of the means for grinding. The workpiece is rotated by the machining tool at a first velocity in a first direction, preferably in the range of about 200 to 20,000 surface feet per minute ("sfm") in a clockwise or counter-clockwise direction. The means for grinding is also rotated by the machining tool at a second velocity in a second direction, preferably in the range of about 500 to 120,000 surface feet per minute (sfm) in a direction opposite that of the direction of the workpiece. The ratio of the velocity of the means for revolving the workpiece to the means for grinding may be 500 sfm to 10,000 sfm. The methods of use of the super-abrasive machining tool described herein remove material at a higher efficiency and shorter period of time than prior methods, such as turning, by grinding the workpiece at a greater velocity in a direction opposite its own movement. While applying any of the methods and grinding tools contemplated herein, any suitable coolant and/or lubricant may be applied to the means for grinding and the surface of the workpiece while the material is being removed.

[0015] The super-abrasive machining tool and method described herein allows material to be removed at much greater

speeds and lower loads which avoid causing damage to the workpieces being machined. The super-abrasive machining tool also allows heat to be dissipated very quickly, which helps avoid the formation of bent grains or white layers in the microstructure of the workpiece and provides better surface finishes. Still further, the super-abrasive machining tool has an increased tool life of potentially hundreds of hours compared to an amount of minutes for tools used in turning processes. The super-abrasive machining tool of the present invention is also faster at removing material than present turning processes and thus economically beneficial. Yet another advantage of the super-abrasive machining tool and methods described herein is its application to superalloys, nickel alloys, and titanium alloys, as well as its potential application to ceramic materials, due to the hardness of these materials and the expense and time required to machine such superalloys with conventional turning processes.

[0016] It is to be understood that the invention is not limited to the illustrations described and shown herein, which are deemed to be merely illustrative of preferred embodiments of the invention, and which are susceptible to modification of form, size, arrangement of parts, and details of operation. The invention rather is intended to encompass all such modifications which are within its scope as defined by the claims.

Claims

1. A super-abrasive machining tool apparatus comprising:

means (12) for grinding a workpiece (18; 46) comprising an exterior surface including a super abrasive material coating, wherein said means (12) for grinding is adapted to revolve at a first velocity in a first direction;
means (24) for cooling said means (12) for grinding; and means (14) for revolving said workpiece, wherein said means (14) for revolving is adapted to revolve in a second direction at a second velocity less than said first velocity.

2. The apparatus of claim 1, wherein said means (12) for grinding comprises a grinding tool.

3. The apparatus of claim 2, wherein said grinding tool comprises a contoured exterior (42).

4. The apparatus of any preceding claim, wherein said grinding tool (12) is selected from the group consisting of a wheel, a quill and combinations comprising at least one of the foregoing grinding tools.

5. The apparatus of any preceding claim, wherein said grinding tool (12) is adapted to be positionable at an angle to said workpiece (18; 46).

6. The apparatus of any preceding claim, wherein said workpiece (18; 46) being ground comprises a substantially circular shape.

7. The apparatus of any preceding claim, wherein said means (24) for cooling is a cooling nozzle capable of dispensing a cooling fluid.

8. The apparatus of any preceding claim, wherein said first direction is clockwise or counter-clockwise, and said second direction is equivalent to or opposite said first direction.

9. The apparatus of any preceding claim wherein said apparatus comprises a computer operated multi-axis grinding apparatus.

10. The apparatus of any preceding claim wherein said means (14) for revolving comprises a mount (16).

11. A method for super-abrasively grinding a workpiece (18; 46), comprising:

disposing a workpiece (18; 46) in a super-abrasive machining apparatus, wherein said super-abrasive grinding machining apparatus comprises means (12) for grinding and means (24) for cooling said workpiece (18; 46);
rotating said workpiece (18; 46) in a first direction and at a first velocity;
rotating said means (12) for grinding in a second direction and at a second velocity greater than said first velocity;
grinding said workpiece (18; 46) using said means (12) for grinding; and
cooling said workpiece (18; 46) being ground.

12. The method of claim 11, further comprising shaping said workpiece (18; 46) by grinding approximate to a circum-

ference of said part.

13. The method of claim 11 or 12, wherein said first direction is clockwise or counter-clockwise, and said second direction is equivalent to or opposite said first direction.

14. The method of any of claims 11 to 13, wherein said first velocity is about 200 to 2000 surface feet per minute.

15. The method of any of claims 11 to 14, wherein said second velocity is about 500 to 120,000 surface feet per minute.

16. The method of any of claims 11 to 15, wherein said means for cooling is a cooling nozzle (24) capable of dispensing a cooling fluid.

17. The method of any of claims 11 to 16, wherein said workpiece (18; 46) comprises a substantially circular shape.

18. The method of any of claims 11 to 17, wherein said means (12) for grinding a workpiece comprising an exterior surface (42) including a super abrasive material coating, wherein said means (12) for grinding revolves at a first velocity in a first direction; said apparatus comprises means (24) for cooling said means (12) for grinding, and means (14) for revolving a workpiece comprising a mount (16); and wherein said means (14) for revolving revolves in a second direction at a second velocity less than said first velocity.

19. The method of claim 18, wherein said means (12) for grinding comprises a grinding tool which makes contact at an angle at a point on a surface of said workpiece (18; 46) being ground.

20. The method of claim 18, wherein said means (12) for grinding comprises a grinding tool making contact circumferentially at a point on a surface of said workpiece (18; 46) being ground.

21. The method of claim 18, wherein said means (12) for grinding includes a contoured exterior surface (42) capable of imparting a feature to a surface of said workpiece (46) being ground.

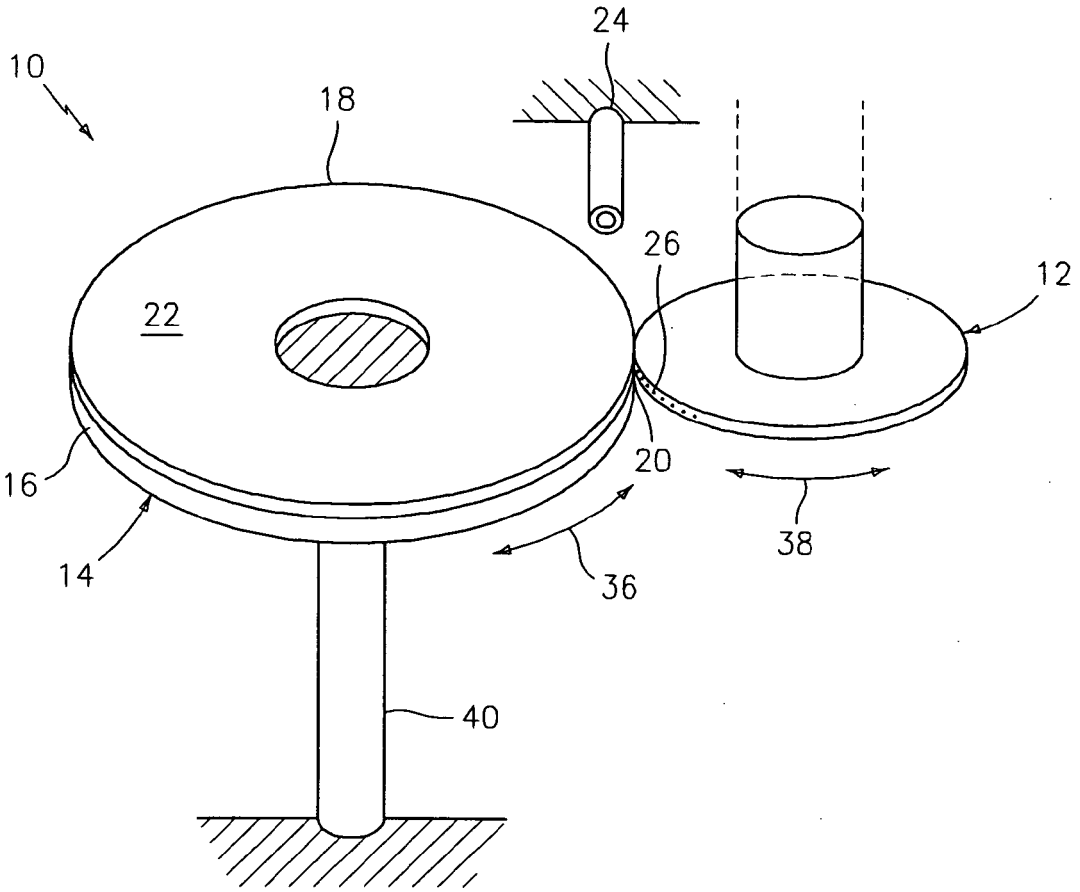

FIG. 1

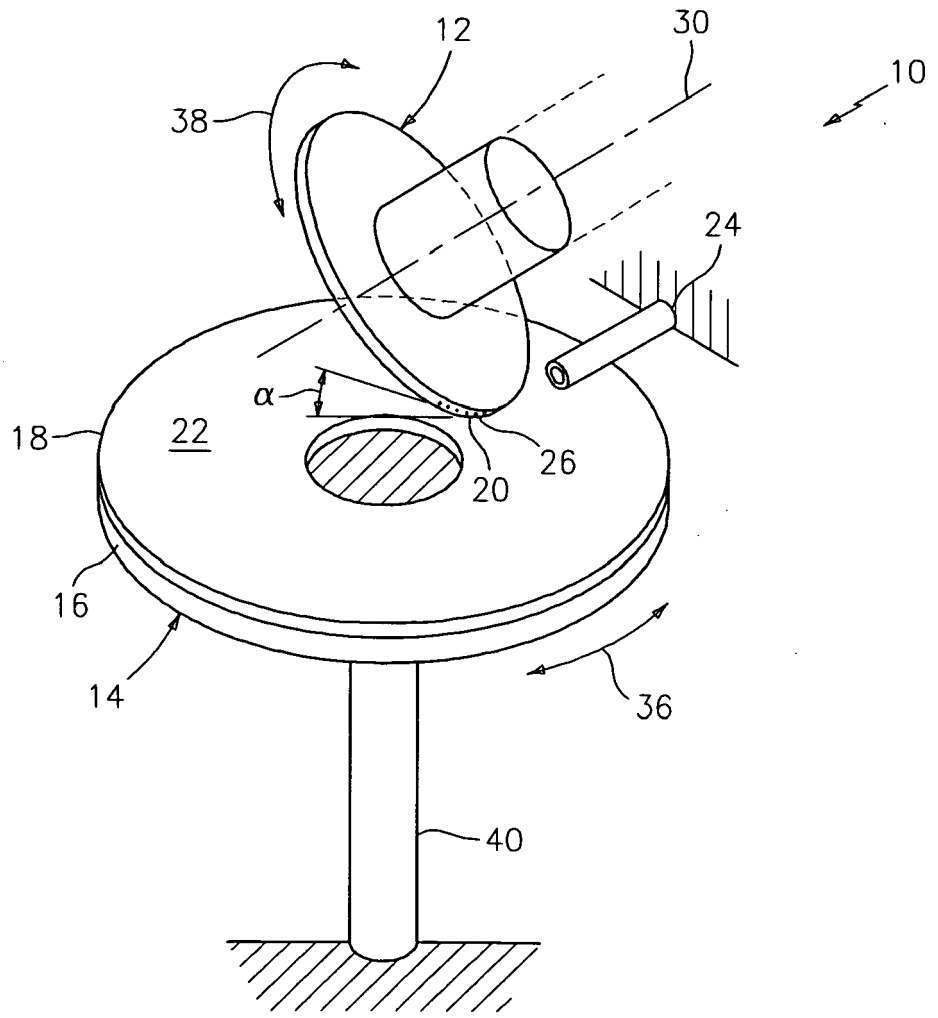

FIG. 2

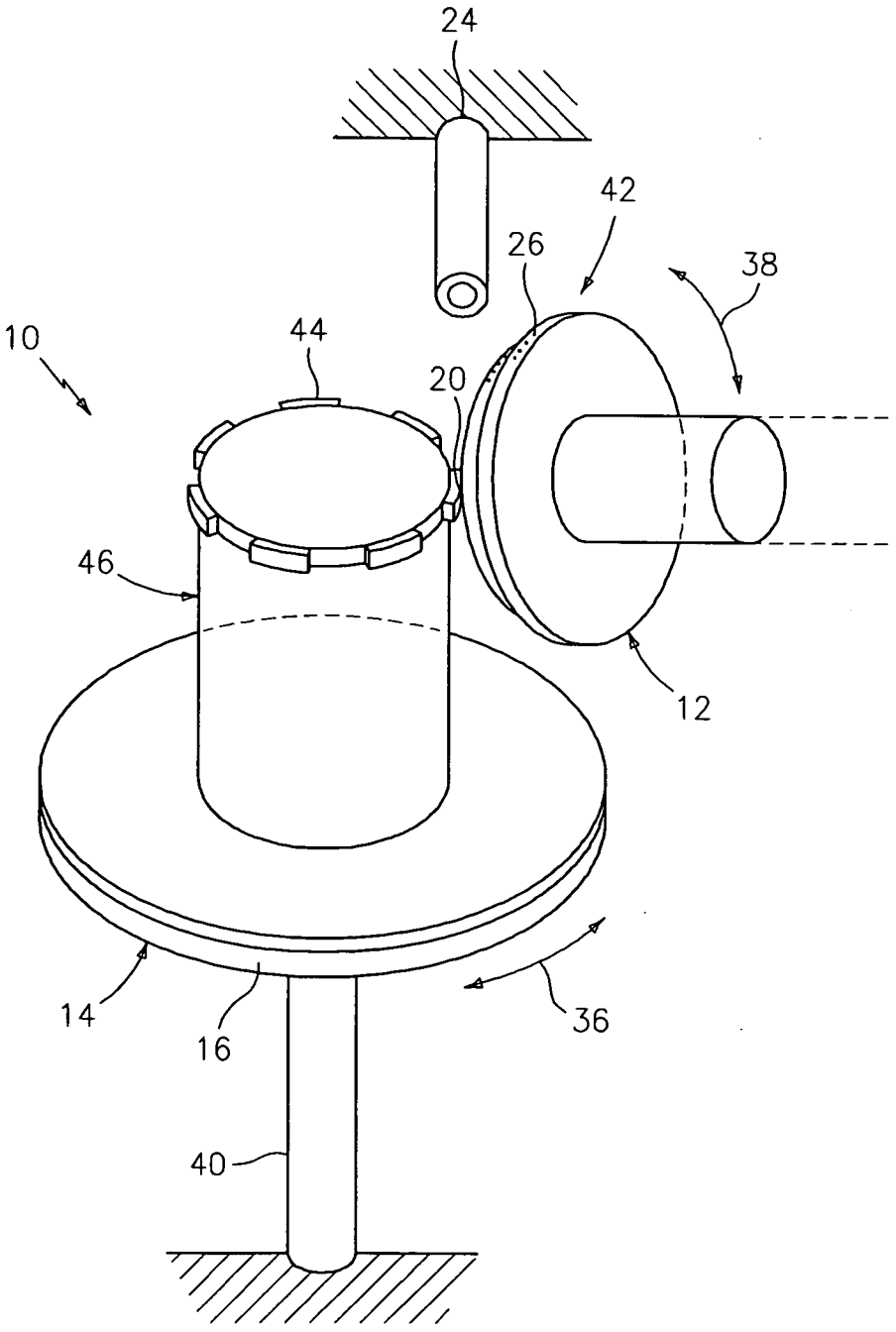

FIG. 3